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HAROLD L. ICKES, SECRETARY

BUREAU OF MINES
JOHN W. FINCH, DIRECTOR

INFORMATION CIRCULAR

FORWARDING HEALTH AND SAFETY IN COAL MINING BY USE OF WATERING METHODS

BY

D. HARRINGTON AND J. J. FORBES

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

FORWARDING HEALTH AND SAFETY IN COAL MINING BY USE OF WATERING METHODS[1]

By D. Harrington[2] and J. J. Forbes[3]

The Bureau of Mines was created in 1910 largely to determine methods of preventing coal-mine explosions; the Bureau's studies have proved that coal dust, except possibly that of some grades of anthracite, can initiate an explosion in the absence of gas, and that its ability to extend or propagate an explosion of either gas or dust has been responsible for nearly all of the widespread explosions that have taken place in bituminous and other non-anthracite mines in the United States in the present century.

It is believed by many persons that all atmospheric dusts may be harmful if breathed in large enough quantities for long enough time; bituminous-coal dust is generally considered to be essentially harmless, physiologically, yet there is abundant evidence of definite damage from inhalation of bituminous dust mixed or unmixed with the dust of other materials. Attention unquestionably should be given to allaying dust in bituminous mines, especially at principal dust-producing sources. This publication enumerates some of the sources of dust and describes practical methods of employing water as one of the most effective of the known methods to allay dust in bituminous mines.

The remedy for air dustiness in bituminous mines is to prevent the formation of dust at the source, insofar as possible, and to provide adequate ventilation to remove or dilute not only the explosive and other gases but also any dust that may be formed in spite of precautions taken to "kill" it at its source. The simplest known method of checking dust formation or, at least, of keeping dust from becoming obnoxious or harmful is to wet the coal or rock with water at the point of contact with the implement or machine. Methods of conducting water to working places and applying it to coal and rock vary in the various sections of the United States.

1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used:"Reprinted from Bureau of Mines Information Circular 7041."
This circular is a preliminary issuance of material that later will be included in a more detailed and extensive technical paper by D. Harrington, J. J. Forbes, F. E. Cash, E. H. Denny, C. A. Herbert, D. J. Parker, C. W. Owings, and A. U. Miller.

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One of the earliest methods of combating the explosion hazard was to use water to prevent coal dust from being ignited or from being raised in a cloud in case of an explosion. One of the first methods used was to sprinkle or wet road beds by means of water cars. Water was first thrown from the tank car with buckets or was allowed to run from the tank onto the center of the road bed. Next, perforated pipes were placed at the rear of the tanks, which allowed wetting of only the road bed; but improved types were developed in which a pump was used to provide enough pressure to sprinkle the roof and ribs as well as the floor. Later, the tank cars were replaced or supplemented in some mines by pipe lines with connections for fixed sprays or for hose, so that the surface of the passage-ways could be thoroughly wetted.

The latter method was first used in the United States in some of the gassy mines in Utah at least as early as 1890 and became standard practice in all of the coal mines (nongassy as well as gassy) in that State when the Winter Quarters disaster of May 1, 1900, with its 200 fatalities, proved beyond a doubt that coal dust can be ignited to initiate an explosion (even when no explosive gas is present) and can also propagate or extend an explosion throughout a mine. The Eastern States were slow to follow the example of Utah; as early as 1912, however, this watering system had been installed at a few mines in Pennsylvania and possibly in a modified manner in other States. About the same time, exhaust steam and water sprays were introduced in a few mines to humidify the air in the belief that this would saturate the ingoing air and prevent it from abstracting moisture from the mine surfaces and thereby dry the dust and aid in the extension of explosions. Steam and water sprays are employed to some extent to the present time, and unquestionably they have some merit as preventives of explosions as well as for other purposes.

Shortly after the Bureau of Mines began to study coal-mine explosions, tests showed that rock dust was a more nearly permanent and in many ways a better means of preventing widespread coal-mine explosions than water, and today, rock dusting is largely accepted throughout the United States as the most dependable method of protecting coal mines from widespread explosions due to coal dust. With the introduction of this method, less thought was given to watering methods; actually, each supplements the other, and there is now a definite trend, not only in the United States but also in some European countries, to use a combination of rock dusting and watering methods to bring about safer and more healthful conditions in coal mines. Rock dust is more lasting than water, but its application is attended by several difficulties, one being that it cannot be applied closer than approximately 15 feet from the coal face, which leaves the most hazardous area in a coal mine unprotected.

Not only is most of the explosive gas released at or near the face, but probably as much as 95 percent of the dust in most coal mines is formed at the face, and unless the coal dust is "killed" at its source, the rock dust, not only in the face region but throughout the mine, will become mixed with large quantities of coal dust, reducing its effectiveness. In many such instances a false sense of security will be felt and other precautionary

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practices may be relaxed. Consequently, water should be used fairly freely in the face region beyond the rock-dusted area and during such mining operations as cutting, shooting, and loading. The use of water to wet dust along haulage roads helps to prevent it from being raised into the air during haulage, and attention is now being given to devising suitable methods of keeping the floor of haulage roads (especially main haulage roads) damp to wet and simultaneously keeping the walls or ribs as well as roof and timbers well-coated with a suitable rock dust. Sprays applied to the top of loaded cars prevent the coal from drying out while the trips are hauled to the dumping point; tests made to determine moisture content of coal on top of cars wetted before they left the working place and when they reached the dump showed that several percent of moisture is lost during a trip of a few miles in intake air at relatively high velocity. Therefore, it is highly advisable that high-pressure sprays should be used on gathering partings and coal dumps as well as at any underground places or in connection with equipment or processes that throw dust into the air. The cost of water used at the working face, at partings, and at dumps may be wholly offset by retarding of the retrogression or degradation of the rock dust, thereby eliminating several applications of rock dust per year on many main haulage roads. In some mines, tests have shown that a well-applied coating of rock dust may retain its effectiveness several years after application on haulage roads in mines where adequate watering is practiced.

The amount of water required is not excessive; the quantity varies from region to region or even from mine to mine. About 2 gallons of water per square foot of undercut, if applied constantly and efficiently, will aid greatly in preventing excessive dustiness of air from undercutting of coal. This mining operation is one of the worst offenders in making coal mines hazardous from either the health or the safety point of view.

Some limited tests made under normal, average working conditions in active coal mines indicate that failure to employ water to allay dust, as compared with fairly effective use of water, show that dustiness is doubled for shearing and topcutting and is increased 5-1/2 times for undercutting, more than 5 times for mechanical loading, more than 7 times for hand loading, nearly 8 times after blasting, and 11 times for hand drilling. When machine cuttings are loaded dry, the dustiness under some conditions is more than 30 times as great as when water is employed. An average of all operations shows that proper application of water decreases the dust to about one-sixth of the amount raised into suspension by dry methods. The preliminary tests and observations made in these very limited studies indicate that with minor changes in the method of applying water, even greater reduction in dustiness may be obtained. There is no reason why the reduction should not be such that not more than about one-twentieth of the dust gets into the air for undercutting or one-twenty-fifth for hand loading.

Water for allaying dust in coal mines may be supplied by at least two methods. Tanks have been designed to be placed on top of mining machines to act as a cover as well as a reservoir, and separate trailing tanks also have been employed to supply mining machines with water. Complete pipe-line systems have been installed in most of the mines now using water for dust control;

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this is considered the best method of supplying water (see figs. 1 and 2).

Water for allaying dust may be taken from the pipelines in the mine; from mine water pumped either to a tank in the mine at a higher elevation than the working places, such as on a slope or to tanks on the surface; from surface streams; or from deep wells; or it may be purchased from city or other water companies. As a rule, the water pressure is maintained at 50 to 110 or up to 150 pounds per square inch; pressures much higher or lower than the above are likely to be ineffective.

Main pipes range in diameter from 2 to 6 inches, with an average of 4 inches. Where 6-inch pipe is employed, the diameter is reduced to 4, 3, or 2 inches on secondary entries and to about 1 or in some instances 3/4 or even 1/2 inch in rooms. The pipes in most room or panel entries are 2 inches in diameter and in rooms 1/2 to 1-1/2 inches in diameter, although the predominant size is 3/4 inch. In most mines hose is 3/4 inch in diameter, except where the smaller pipe is used; generally, the 3/4 inch size is the smallest that should be employed to be assured of reasonably efficient service.

The general practice for wetting machine cuttings is to apply water to the mining-machine chain and allow the water to be carried into the kerf to wet the dust as it is formed (figs. 3-5). The methods of accomplishing this purpose vary. A steel pipe or even a rubber hose is attached to the motor housing and arranged to allow water to fall from the end of the hose or pipe--a distance of 4 to 6 inches--onto the chain, bits, or cutter bars at the housing. The most effective arrangement with this method apparently was where the pipe was connected to an adjustable bracket, which allowed the stream of water to be directed into the chain guide on the intaking bits as they emerged from the motor housing.

A transition type between application of water at or near the housing and application at the end of the bar is an iron pipe extending along a channel in the center of the cutter bar to the end of the bar. Water discharges from this pipe at its extremity and from nine 1/8-inch holes, 3 inches apart, escapes through similar holes in the guide, and discharges into the chain guide on the intake side of the chain as the bits move into the kerf; if this type of installation is made in an efficient manner, it should give satisfactory results.

In the Alabama district, many mining machines have a small pipe, extending along an opening in the center of the cutter bar to the end of the bar. A hole is made through the guide, and the water wets the dust as it is formed at the end of the cutter bar; water also is carried with the bits to wet the coal cuttings as they are formed. A variation of this method involves bending the pipe at right angles near the end of the cutter bar and allowing the water to discharge onto the bits as they pass around the head of the bar.

In still another variation a pipe is extended in the center of the cutter car to within a foot or 18 inches of the end of the bar. The pipe

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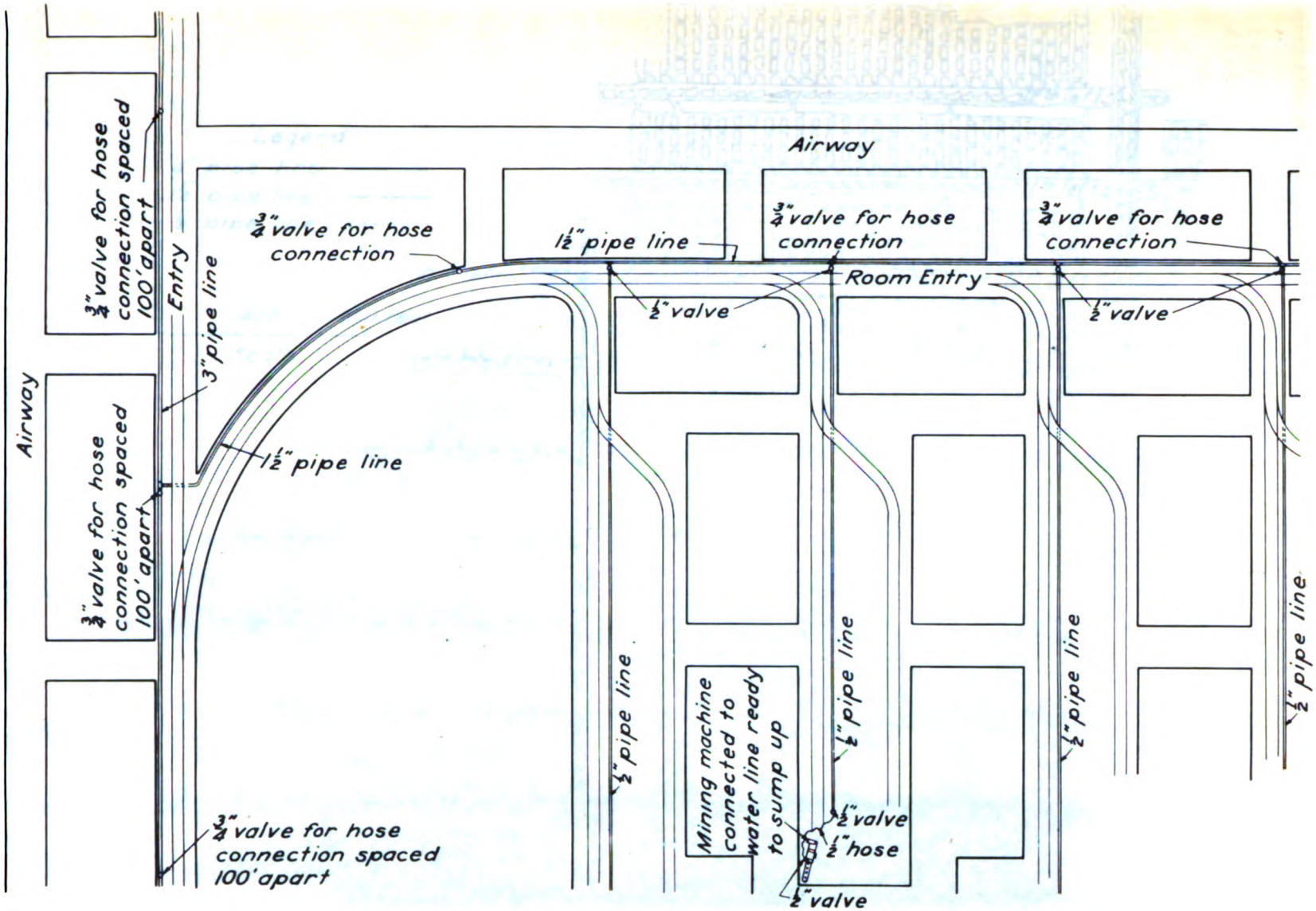

Figure 1.—Standard water-line system for coal mines.

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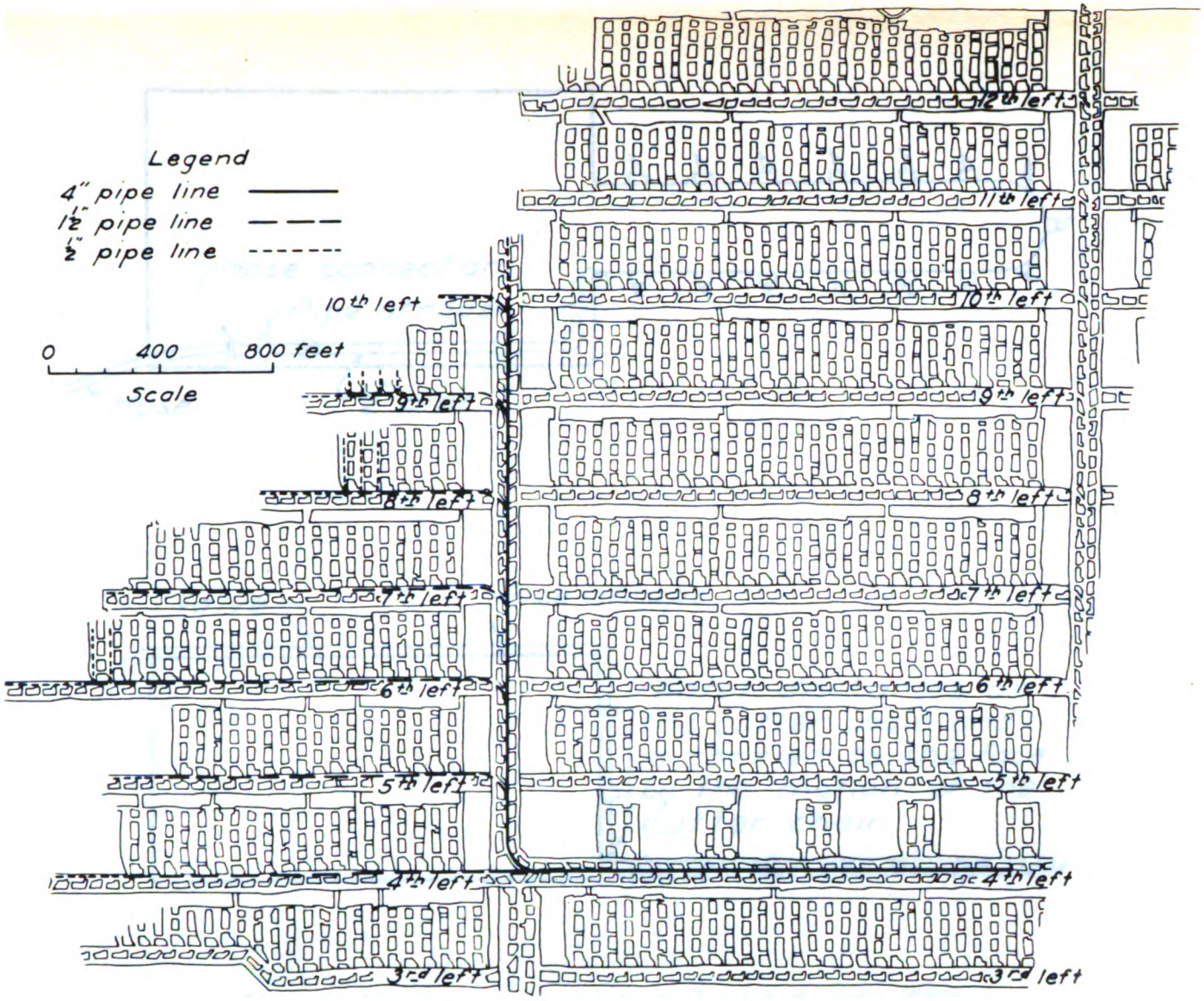

Figure 2.—Part of mine showing location of water pipe line.

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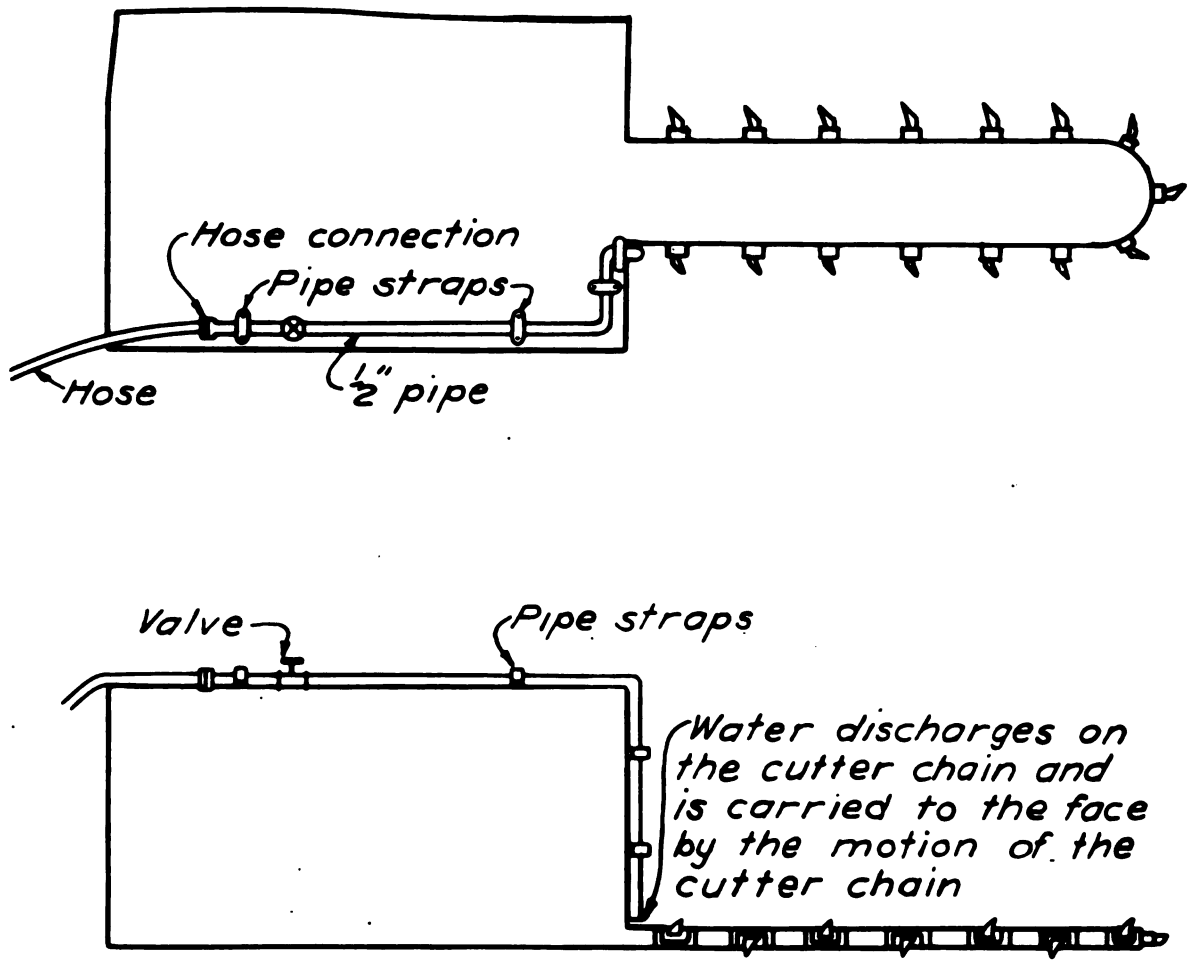
Hose connection
Pipe straps
Hose
½" pipe
Valve
Pipe straps
Water dischorges on the cutter chain and is carried to the face by the motion of the cutter chain

Figure 3.—Sketch showing application of water on cutter chains.

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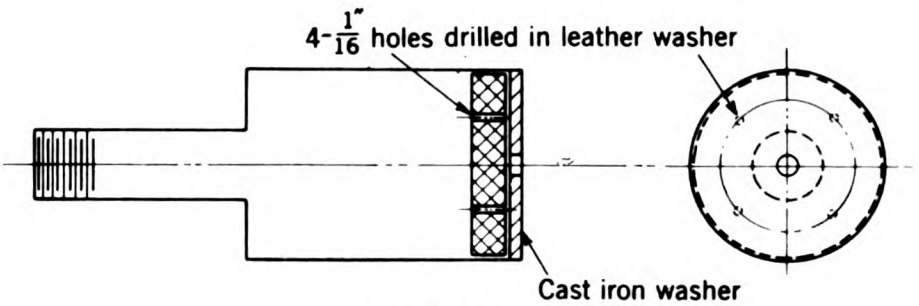
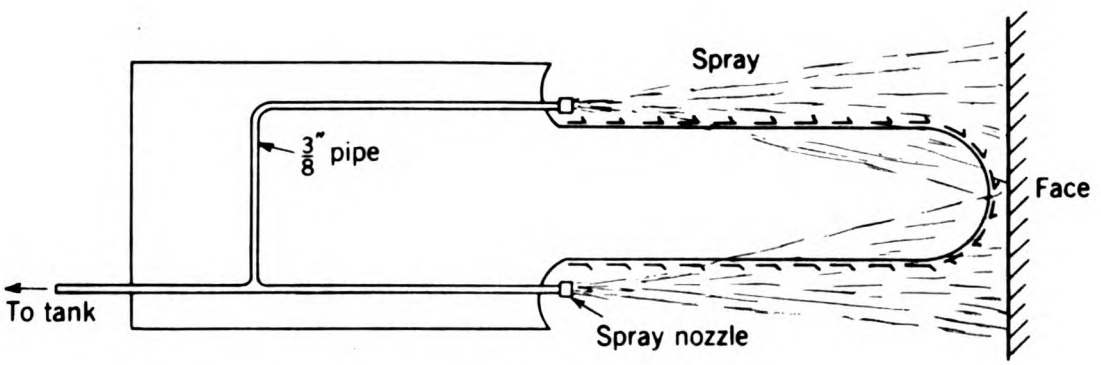


Detail of spray



Top view of cutting machine

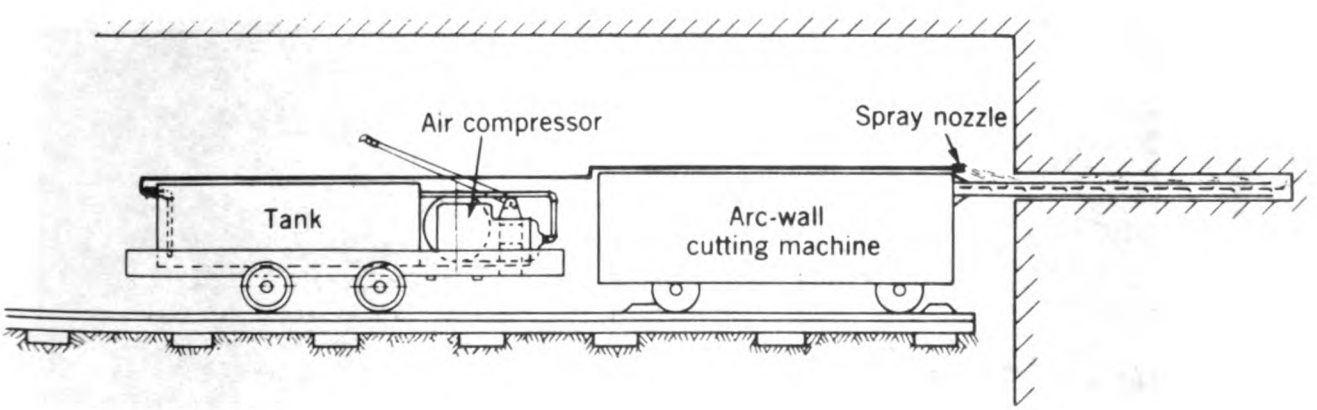


Figure 4.—Side view of cutting machine and water tank for spraying water while cutting.

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Figure 5.—Cutting machine in operation showing water spray.

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Figure 6.—Wetting the coal face.

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Figure 7.—Tops of loaded coal cars being sprayed with water.

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terminates in a T section, which extends to the chain guide on each side near the end of the cutter bar. This provision enables the water to wet the coal at two points. One type of mining machine is provided with a pipe leaving three openings about 2 feet apart on the return side of the cutter bar.

Other variations are found in practice. One type of mining machine has a spray nozzle on the return side of the cutter bar at the housing. Another construction consists of two pipes, one on each side of the cutter bar; they terminate in a nozzle formed from grease cups, in which four small holes have been drilled. The water is sprayed at the coal face and not onto the bits. At one mine a pipe is attached to the motor housing and extends across the bar. A number of small holes drilled in the pipe allow the water to cascade down onto the cutter bar and chain and wash down the dust as it is formed and emerges from the kerf. Practically the same types are used for applying water on top-cutting or shearing machines as on shortwall machines.

Water is used during drilling in coal to only a very slight extent, if at all, though wet-drilling of rock is done in some coal mines; however, in some mines the coal face is wetted thoroughly before it is drilled; this is a distinct aid to dust reduction. Practice during blasting ranges from no use of water to a thorough wetting before and after each blast. The latter method is by all means the most effective, as it provides a means of allaying dust on the face, ribs, roof, and floor before the first shot is fired and allows the water to soak the blasted-down coal between blasts. Application of water after a blast quickly removes the dust and fumes from the air, allowing men to return to the working face much sooner and with much less discomfort and possible harm to health than when no water is applied (fig. 6).

During loading of the first, second, and last cars, the maximum amount of dust generally is thrown into the air. The first two cars are likely to contain many of the machine cuttings, and unless enough water has been used during cutting and before loading is begun, dense clouds of dust usually are thrown into the air. The best method is to wet the coal pile thoroughly before beginning to load the coal and to apply water at frequent intervals during loading. Merely wetting the top of the pile is not sufficient; the water should be allowed to run down through the interstices. Water should also be directed at the back of the cut and allowed to run down into the pile to wet the dust formed by the greater shattering of the coal at the back of the shot hole by the explosives.

The top of the car should be wet after it has been loaded (see fig. 7). Water sprays are used in some mines to wet the top of loaded cars on partings and at dumps, either underground or on tipples, In a few mines, empty cars are also watered before they are returned to the working places--a decidedly good safety procedure. All of these systems are precautions to keep dust out of the air; the so-called "sprays" used to wet the top of loaded cars usually are more than that. The holes in the pipe are relatively large and allow a strong, large stream of water to fall on the cars; and the water drenches the top of the coal and percolates through the interstices,

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wetting some of the underlying coal as well. If the face has not been wetted during cutting and loading, sprays do not wet the coal effectively; on the other hand, if the machine cuttings are thoroughly wetted, the coal pile is kept wet while loading is done, and the top of the car is wetted before the car is hauled from the working place, supplementary watering by sprays on the partings is not always necessary. If coal is dumped underground, however, it is always advisable to use water as a wetting fluid as the cars are dumped.

Considerable experimentation on "dedusting" coal is in progress, and a number of coal companies have installed spray nozzles for applying water, calcium chloride, oils, and similar substances on the coal to reduce dustiness as it is dumped, screened, and sized. The cleanness of coal so treated is said to have appealed to domestic consumers. "Dedusting" and wetting could be combined to reduce dustiness. Tests have been made with one of the water-soluble flake-type dust-wetting agents, and while the results were not commercially satisfactory, this or possibly some similar type of dust-prevention device or method has definite possibilities. The difficulty in the tests was that the spray was not fine enough to be effective. For oil treatment, pressures of 300 to 600 pounds per square inch frequently are employed to obtain a definite fog, whereas in the tests only a fine spray was realized. Future research in the application of water in coal mines during cutting of coal, possibly during mechanical loading and at dumps underground or on tipples, probably will be largely with the finer mist or fog. Some mine operators object to adding moisture to the coal, and the finer spray probably will reduce the amount of water necessary to be used, and some method may be devised to make it effective. Where very finely divided dust is formed, as when rock is cut, the finer spray promises to be more effective in allaying the dust than the present method of employing coarse sprays or streams of water.

The quantity of water most effective in cutting coal has not been accurately determined at most mines, but estimates have been submitted that range from 27 to 87 gallons per cut. (The width of the places cut has not been given in all instances.) One large operation averages 38.5 gallons of water per undercut of 120 square feet, or 2.57 gallons of water per linear foot and 0.32 gallon per square foot; in another mine, however, the average is reported as 2 gallons per square foot, but this seems excessive. The effectiveness of the wetting, however, is not always measured by the quantity of water used; under certain conditions, much water may throw more dust into the air than would a smaller flow. The amount of water used on cutting machines is a mean of about 2 gallons per ton of coal; with approximately this quantity of water used in a fairly effective manner, the atmosphere was relatively free of dust, and the fines from the machine cuttings apparently were not thrown into suspension to any considerable extent by subsequent agitation.

When the coal operator considers the immense amount of dust unavoidably made due to local operating, climatic, stratigraphic, and other condition, and then considers the inflammability of the dust and gas found in his mines, and when he considers that under some condition, unless the dust is mixed with about four times its own bulk of very fine rock dust, he cannot prevent it

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from propagating an explosion, he naturally feels somewhat dubious about relying on rock dusting alone; and, as his faith in water methods alone is somewhat shaken also, calm consideration of all the elements that enter into the matter places him in the position of the little boy who, when asked whether he would have mince pie or lemon pie, replied that he'd have a little of both.

One of the most disastrous of relatively recent coal-mine explosions was started by ignition of extremely fine road dust that had settled on timbers out of the air of an intake haulage road. This dust had an incombustible content (rock dust plus moisture) of about 65 percent; on the other hand, when virtually pure coal dust from this property was mixed with 8 percent water and subjected to standard ignition tests (which ignite the dry dust at every attempt), the dust with 8 percent water mixed did not ignite. Dry coal dust of the same size, when mixed with dry rock dust, making 58 percent incombustible, propagated an explosion readily; and when there was about 1 percent methane in the air, an explosion was propagated through the dry dust when 66 percent incombustible was present. When one considers this, one is likely to infer that at least as far as ignition is concerned moistening is to be preferred to rock dusting; and since face operations, such as undercutting, overcutting, shearing, drilling, shoveling, blasting, or pillar pulling all throw into the air much finely divided coal dust, to settle out later on props, timbers, caps, floor, rib and roof ledges, and rock gob, it is readily apparent that face regions are likely to be decidedly dangerous as to fine coal dust. As flame for ignition is found most frequently at or around the face region in open lights and methane accumulations, or in electric arcs and methane or dust or both, or in blown-out shots and methane or dust, it is extremely desirable that the dust near faces be "killed" and kept "dead" at all times. Since 65 percent incombustible will not prevent ignition of some very fine coal-mine dusts and under some circumstances, such as the presence of 2 to 3 percent of methane, even 80 percent incombustible would fail to prevent ignition while as little as 8 percent of water does prevent ignition, naturally it is felt advisable, even necessary, to use water around the working faces. In some progressive coal mines the first act of each miner after coming on shift is now to wet down the face region (including ribs, roof, and floor), coal pile, and exposed parts of the face. Water is also used to sprinkle tops of all loaded cars before they leave the face, to sprinkle face regions at least once or twice during the middle of the shift and as the last act before the miner leaves his working place in the mine. The dreaded "bug dust" menace is removed entirely by the simple expedient of using a spray of water on the ingoing side of the cutting chain of all mining machines. The use of water around the face region, in addition to "killing" the dust as far as aiding in ignition or propagation of an explosion is concerned, also keeps out of the air the enormous clouds of fine coal dust, which are certainly detrimental to health of workers, particularly the machine runners. On the other hand, failure to use water at the face when rock dusting is done intensifies the probable health hazard to face workers from breathing dust suspended in the air. This is especially true of the face region, because air currents are likely to be sluggish or virtually nonexistent at some faces, particularly those of rooms or pillars; hence, when the very fine dust is thrown into the air by blasting, shoveling, or other operation, it may remain suspended for hours, to be breathed by workers.

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Moreover, unless the dust is "wet down" at and around the face regions, it is certain that fine, dry coal dust from faces and from the top of or through openings in cars will soon settle upon adjacent rock-dusted surfaces; and the 15 to 30 percent of combustible that makes some of our coal-mine dusts inflammable will be found to make rock dusting ineffective almost as quickly as evaporation renders sprinkling ineffective. Recently, a sample of very fine combination settled, and rock-dusted dust was collected from the rib of a dry main-intake main-haulage road in a mine where water was used very sparingly at the face and not at all on the top of cars; when the dust was taken to the surface and allowed to sift over a lighted match, the resultant "flare-up" was decidedly indicative that rock dusting, to prevent explosion ignition or propagation, must be renewed frequently where coal dust is not "killed" by water at the face region or elsewhere in the interior of the mine.

One of the worst difficulties experienced where main-haulage intake entries are rock-dusted is the fact that, owing to the use of loose or open-type cars or to high topping of cars or to both, much coal is spilled along the tracks; this soon becomes fine and dry and, upon being thrown into the air by passing cars, animals, and men, settles upon roof, walls, and floor and makes rock dusting ineffective in a short time. Although the ultimate remedies for this would be to adopt a tight car and to restrict topping, neither remedy can be applied readily; it is now proposed in some mines, therefore, to run a water car along haulage entries to keep wet the region between and immediately outside of the track rails and meanwhile to make every effort to prevent coal from being spilled and to clean up any that may be spilled. Here, again, it can be seen that some coal operators have faith in watering even where rock-dusting is used as the chief explosion-prevention measure.

Failure to keep open abandoned or nonworking places well-sprinkled has been responsible for the spread of explosions in mines where sprinkling systems have been in use. These open, nonworking regions are very dangerous and, if they cannot be sealed, should be kept either well-sprinkled or well-rock-dusted. Where such regions cannot be traveled, stationary water sprays that run continuously are being used extensively in one mining region; but, by all odds, the safest method is sealing where this is feasible.

It has been stated frequently that fine, dry coal dust either will not mix with or absorb water or will do so only with difficulty or delay. Years of experience in coal mines in the western part of the United States prove that, even in mines where there is no shale or slate admixture to aid in absorbing moisture and where the coal is oily (the oil actually issuing from the coal floor or roof in places), even newly deposited, very fine, dry dust can be easily moistened if the underground workings are sprinkled systematically and are not allowed to become "bone" dry before water is again applied. However, where sprinkling is haphazard and successive applications of water are made only after the workings have become dangerously dry, it is difficult to moisten fine dry coal dust, and often it will float for days or even weeks remaining absolutely dry upon a pool of water. One of the most mistaken ideas with regard to the use of water in coal mines is that a mine usually is

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considered to be sprinkled when a water car or hose is run over a few workings once every week, month, or year and a little water is thrown between the rails on the floor. Really effective sprinkling requires that ribs, roof, timbers, and floor be washed down thoroughly and never allowed to become dry. If this is not done, a mine is not well-sprinkled. If it is done, the ribs, roof, and timbers will be kept free of dust and on the floor the very fine, hence dangerous, dust will be either washed down under the coarse coal to the solid floor or be attached to larger pieces in such manner that only a violent explosion can bring it into suspension even if it should become dry. A sample of floor dust taken across the width of an entry in a 6-inch groove about 1 inch deep, where no sprinkling or watering had been done, gave 31 percent through 200 mesh, while a sample taken in the same mine in a near-by place that was kept fairly well watered gave but 11 percent through 200 mesh. At the time of sampling, both places were fairly dry, but the place with only 11 percent through 200 mesh had usually been kept well sprinkled or watered. This is typical of the coarseness of the exposed floor dust where real watering is done.

Another fallacy as to effective use of water is that when water is placed on the roof, ribs, or floor damage results from caving, sloughing, squeezing, etc. While it is probably true that at first there will be some falls or similar temporary trouble and possibly, in a few isolated instances, even permanent difficulty, yet very few localities have suffered permanent injury. Many examples have been found where operators believed terrible damage would be done by applying water to ribs, roof, or floor and later, when forced by some emergency actually to try it, they found that the dreaded danger failed to materialize. Many mines east of the Mississippi River that experience sloughing of roof or ribs, due to alternate "sweating" and drying, could overcome this difficulty by adopting effective watering methods in the dry seasons in places where water will not freeze.

It appears that both sprinkling and rock dusting should be done in every coal mine--the sprinkling largely at or around the face, the rock dusting in the entries, particularly those on intake air. Both methods should cover ribs, roof, floor, and timbers. Both methods must be maintained, and to do this constant and continuous supervision must be exercised, and much rock dusting as well as sprinkling must be done continuously. If efficient sprinkling is not done at the face, not only will ignitions be made easier and more frequent, but the coal dust from dry "bug dust" from blasting, shoveling, etc., at the face and from the top of loaded cars and bottom of empty cars, as well as from coal spilled on roadways, will, within a very short time, cause rock-dusted ribs, floors, roof and timbers of entries, abandoned workings, etc., to be so covered with fine dry coal dust as to constitute a hazard for feeding flame and propagating an explosion. How easily this can happen can readily be understood when it is considered that a mixture of 25 percent of the very fine dry coal dust that settles out of the air and 75 percent of rock dust will readily propagate an explosion in some mines. It is probable that in some cases 20 percent or less of very fine, dry coal dust in a rock dust-coal dust mixture will propagate an explosion.

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It is now apparent that rock dusting in coal mines without the simultaneous use of water at the face is analogous to such abominable practices as adopting electric safety lamps and allowing smoking at the face; or requiring the use of electric safety lamps and blasting with fuse and black powder; or spending money on electric safety lamps and saving money by slowing down the fan or reducing the amount expended on overcasts, stoppings, or brattice cloth. Whether sprinkling is used or rock dusting is put into operation, or even if both are used (and certainly this should be the practice mine operators should be constantly vigilant that such precautions are renewed often, that ventilation is good, that open lights or any kind of flame underground are restricted or prohibited, that abandoned territory is sealed, that none except permissible equipment maintained in safe permissible condition is used, and that other up-to-date mining practices are extended, rather than relaxed or abandoned.

In connection with rock dusting of coal mines, it is strange that while attention and money are being spent to make mining safer, mining men of the United States make little or no use of the wealth of information on rock dusting prepared for them by the Federal Bureau of Mines. This is especially true of the data in Bulletins 20 and 167 and Technical Paper 84. It would seem that these publications ought to constitute the bible of the up-to-date coal-mine safety men and operators of the United States; the wealth of useful information contained in Bulletin 167, particularly, should be at their finger tips.

Some of the possible benefits of watering to allay coal dust are (1) decrease in the explosion hazard, (2) decline in ill health of workmen, (3) greater efficiency and comfort of workers, (4) better morale, (5) less labor turnover, (6) decline in number of accidents, owing to better visibility, and (7) reduction in the retrogression of rock dust.

Watering is recommended as a supplement to general rock-dusting because it reduces the amount of dust thrown into the air during mining operations and, consequently, in the event of an explosion, the likelihood of dust being thrown into suspension. The effect of coal dust on the health of miners has not been determined conclusively, but the present trend of thought is that any dust breathed for a long enough time in large enough quantities is likely to be detrimental to health. During investigations of dust conditions in coal mines, it has been observed that inhaling dry dust apparently increases the tendency to colds and bronchial irritation.

An increase of approximately 10 percent in efficiency of workers is claimed where water is used to allay dust in some mechanized mines in the Midwest; although much of this increase is probably due to better visibility, other important factors are the lessened discomfort when air-borne dust is reduced and eyes, ears, nose, throat, and lungs are freed of the various hazards that accompany efforts to prevent the dust from afflicting the various parts of the body. Preliminary tests indicate an average increase of about 15 percent in illumination through the use of water to allay dust; other tests, which the authors did not conduct, are reported to have shown a decrease

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in visibility up to 75 or more percent owing to dust in air in mines where cutting was done dry. The clearer atmosphere in mines employing water in the various mining operations unquestionably improves the morale of the workmen, they are likely to be more contented with working conditions, and, as a consequence, labor turn-over is decreased; assuming a decrease of 10 percent in labor turn-over in normal times owing to watering in coal mines, the cost of installing watering systems in many instances will be more than offset by the reduced cost of employing and training new employees.

APPENDIX

The Mine Safety Board of the Bureau of Mines, in its decisions 15 and 17, makes the following recommendations with regard to the use of water to decrease the formation and distribution of coal dust in bituminous-coal mines:

Mine Safety Board Decision 15

In the interest of safety in coal mining, the Bureau of Mines * * * * recommends that, to lessen the coal-dust explosion hazard:

(a) Machine coal cuttings be wet as the cutting is being done.

(b) The coal face, and the working place 40 feet therefrom, shall be kept free of coal dust by the use of water.

(c) The top of loaded cars in the working place shall be wet.

Mine Safety Board Decision 17

To lessen the formation and distribution of coal dust in haulageways, the Bureau of Mines * * * * recommends that in bituminous and lignite coal mines:

(a) The mine cars should be constructed and maintained dust-tight.

(b) The coal should be so loaded that it will not shake off in haulage.

(c) The cars and loads should be so sprayed as to prevent dust being distributed along the haulageways.

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